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ASTEC DEVELOPMENTS LIMITED [1]; (). SIMPSON, Neil, Andrew, Abercrombie [1]; (). SIMPSON, Neil, Andrew, Abercrombie [1]; (). PACITTI, Paolo; ().

(54) Title: PROCEDURES AND EQUIPMENT FOR PROFILING AND JOINTING OF PIPES

(54) Titre: PROCEDES ET MATERIEL DE FAÇONNAGE ET D'ASSEMBLAGE DE TUYAUXS

### (57) Abstract

Methods and apparatus for shaping pipes, tubes, liners, or casing at downhole locations in wells. Use is made of rollers bearing radially outwards against the inside wall of the pipe (etc.), the rollers being rolled around the pipe to cause outward plastic deformation which expands and shapes the pipe to a desired profile. Where one pipe is inside another, the two pipes can be joined without separate components (except optional seals). Landing nipples and liner hangers can be formed in situ. Valves can be deployed to a selected downhole location and there sealed to the casing or liner without separate packers. Casing can be deployed downhole in reduced-diameter lengths and then expanded to case a well without requiring larger diameter bores and casing further uphole. The invention enables simplified downhole working, and enables a well to be drilled and produced with the minimum downhole bore throughout its depth, obviating the need for large bores. When expanding lengths of casing, the casing does not need to be anchored or made pressure-tight. The profiling/expansion tools of the invention can be deployed downhole on coiled tubing, and operated without high tensile loads on the coiled tubing.

#### (57) Abrégé

L'invention concerne des procédés et appareils de façonnage de tuyaux, tubes, colonnes perdues ou tubages au fond de puits. On utilise des rouleaux disposés radialement vers l'extérieur contre la paroi intérieure du tuyau et on fait rouler les rouleaux autour du tuyau pour provoquer une déformation plastique vers l'extérieur qui gonfle le tuyau et le façonne dans une forme voulue. Lorsqu'un tuyau se trouve à l'intérieur d'un autre tuyau, on peut assembler les deux tuyaux sans recourir à des composants séparés (sauf éventuellement des joints). Des raccords à portée intérieure et des suspensions de colonne perdue peuvent être formés sur place. On peut déployer des vannes dans un emplacement de fond sélectionné puis les assembler au tubage ou à la colonne perdue sans garniture d'étanchéité séparée. On peut déployer le tubage au fond par longueurs de diamètre réduit, puis le dilater pour le transformer en gainage d'un puits sans devoir creuser de trous à diamètre plus large et sans utiliser d'avantage de tubage vers la tête du puits l'invention simplifie le travail de forage et permet de creuser un trou de forage avec un alésage minimal en profondeur, ce qui élimine la nécessité de creuser des trous à large diamètre. Lors de la dilatation d'un tubage, le tubage ne doit pas nécessairement être ancré ou étanche. Les outils de façonnage/expansion de l'invention peuvent être déployés au fond sur un serpentin et actionnés sans provoquer d'efforts de tension élevés sur le serpentin.



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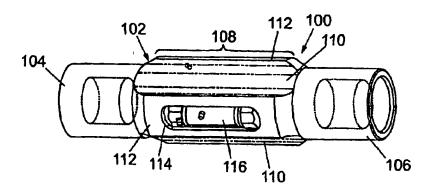
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(54) Title: PROCEDURES AND EQUIPMENT FOR PROFILING AND JOINTING OF PIPES



#### (57) Abstract

Methods and apparatus for shaping pipes, tubes, liners, or easing at downhole locations in wells. Use is made of rollers bearing radially outwards against the inside wall of the pipe (etc.), the rollers being rolled around the pipe to cause outward plastic deformation which expands and shapes the pipe to a desired profile. Where one pipe is inside another, the two pipes can be joined without separate components (except optional seals). Lunding nipples and liner hangers can be formed in situ. Valves can be deployed to a selected downhole location and there sealed to the casing or liner without separate packers. Casing can be deployed downhole in reduced-diameter lengths and then expanded to case a well without requiring larger diameter bores and casing further uphole. The invention enables simplified downhole working, and enables a well to be drilled and produced with the minimum downhole bore throughout its depth, obviating the need for large bores. When expanding lengths of casing, the casing does not need to be anchored or made pressure-tight. The profiling/expansion tools of the invention can be deployed downhole on coiled tubing, and operated without high tensile loads on the coiled tubing.

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# Description

10 PROCEDURES AND EQUIPMENT FOR 15 PROFILING AND JOINTING OF PIPES. 2 3 This invention relates to procedures and equipment for 20 profiling and jointing of pipes, and relates more 4 5 particularly but not exclusively to methods and apparatus for the shaping and/or expansion and/or conjoining of tubular casings in wells. 7 25 In the hydrocarbon exploration and production industry 8 9 there is a requirement to deploy tubular casings in 10 relatively narrow-bore wells, and to expand the 30 deployed casing in situ. The casing may require to be 11 12 expanded throughout its length in order to line a bore 13 drilled through geological material; the casing may 14 additionally or alternatively require to be expanded at 35 15 one end where it overlaps and lies concentrically 16 within another length of previously deployed casing in 17 . order to form a swaged joint between the two lengths of 18 casing. Proposals have been made that a slotted metal 40 tube be expanded by mechanically pulling a mandrel 19 20 through the tube, and that a solid-walled steel tube be 21 expanded by hydraulically pushing a part-conical ceramic plunger through the tube. In both of these 22 45 23 proposals, very high longitudinal forces would be exerted throughout the length of the tubing, which 24 25 accordingly would require to be anchored at one end.

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	1	Where mechanical pulling is to be employed, the pulling
	2	force would require to be exerted through a drillstring
	3	(in relatively large diameter wells) or through coiled
10	4	tubing (in relatively small diameter wells). The
	5	necessary force would become harder to apply as the
	6	well became more deviated (i.e. more non-vertical), and
	7	in any event, coiled tubing may not tolerate high
15	8	longitudinal forces. Where hydraulic pushing is to be
	9	employed, the required pressure may be hazardously
	10	high, and in any event the downhole system would
	11	require to be pressure-tight and substantially leak-
20	12	free. (This would preclude the use of a hydraulically
	13	pushed mandrel for the expansion of slotted tubes).
	14	The use of a fixed-diameter mandrel or plug would make
	15	it impracticable or impossible to control or to vary
25	16	post-deformation diameter after the start of the
23	17	expansion procedure.
	18	It is therefore an object of the invention to provide
20	19	new and improved procedures and equipment for the
30	20	profiling or jointing of pipes or other hollow tubular
	21	articles, which obviate or mitigate at least some of
	22	the disadvantages of the prior art.
nr.		
35	23	In the following specification and claims, references
	24	to a "pipe" are to be taken as references to a hollow
	25	tubular pipe and to other forms of hollow tubular
	26	article, and references to "profiling" are to be taken
40	27	as comprising alteration of shape and/or dimension(s)
	28	which alteration preferably takes place substantially
	29	without removal of material.
	30	
45	31	According to a first aspect of the present invention
	32	there is provided a profiling method for profiling a
	33	pipe or other hollow tubular article, the profiling

5	•	3
	1	method comprising the steps of applying a roller means
	2	to a part of the pipe bore selected to be profiled,
	3	translating the roller means across the bore in a
10	4	direction including a circumferential component while
	5	applying a force to the roller means in a radially
	6	outwards direction with respect to the longitudinal
	7	axis of the pipe, and continuing such translation and
15	8	force application until the pipe is plastically
,-	9	deformed substantially into the intended profile.
	10	The deformation of the pipe may be accomplished by
20	11	radial compression of the pipe wall or by
	12	circumferential stretching of the pipe wall, or by a
	13	combination of such radial compression and
	14	circumferential stretching.
25		
	15	Said direction may be purely circumferential, or said
	16	direction may partly circumferential and partly
	17	longitudinal.
30	18	Cold mallow many is not a second
	19	Said roller means is preferably peripherally profiled
	20	to be complementary to the profile into which the
	21	selected part of the pipe bore is intended to be formed.
35	2.1	Tormed.
	22	The selected part of the pipe bore may be remote from
	23	an open end of the pipe, and the profiling method then
	24	comprises the further steps of inserting the roller
40	25	means into the open end of the pipe (if the roller
	26	means is not already in the pipe), and transferring the
	27	roller means along the pipe to the selected location.
	28	Transfer of the roller means is preferably accomplished
45	29	by the step of actuating traction means coupled to or
	30	forming part of the roller means and effective to apply
	31	along-pipe traction forces to the roller means by

5 1 reaction against parts of the pipe bore adjacent the 2 roller means. 3 The profiling method according to the first aspect of 10 the present invention can be applied to the profiling 5 of casings and liners deployed in a well (e.g. a hydrocarbon exploration or production well), and the profile created by use of the method may be a liner 15 8 hanger, or a landing nipple, or another such downhole profile of the type which previously had to be provided 9 10 by inserting an annular article or mechanism into the 11 well, lowering it the required depth, and there 20 anchoring it (which required either a larger diameter 12 13 of well for a given through diameter, or a restricted through diameter for a given well diameter, together 14 15 with the costs and inconvenience of manufacturing and 25 16 installing the article or mechanism). Additionally or alternatively, the profiling method according to the 17 18 first aspect of the present invention can be applied to increasing the diameter of a complete length of pipe; 19 30 20 for example, where a well has been cased to a certain 21 depth (the casing having a substantially constant diameter), the casing can be extended downwardly by 22 23 lowering a further length of pipe (of lesser diameter 35 such that it freely passes down the previously 24 25 installed casing) to a depth where the top of the 26 further length lies a short way into the lower end of the previously installed casing and there expanding the 27 40 28 upper end of the further length to form a joint with the lower end of the previously installed casing (e.g. 29 by using the method according to the second aspect of 30 31 the present invention), followed by circumferential expansion of the remainder of the further length to 32 match the bore of the previously installed casing. 33

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5	•	5
	1	According to a second aspect of the present invention
	2	there is provided a conjoining method for conjoining
	3	two pipes or other hollow tubular articles, said
10	4	conjoining method comprising the steps of locating one
	5	of the two pipes within and longitudinally overlapping
	6	one of the other of the two pipes, applying roller
	7	means to a part of the bore of the inner of the two
15	8	pipes at a location where it is intended that the two
	9	pipes be conjoined, translating the roller means across
	10	the bore in a direction including a circumferential
	11	component while applying a radially outwardly directed
20	12	force to the roller means, and continuing such
	13	translation and force application until the inner pipe
	14	is plastically deformed into permanent contact with the
	15	outer pipe and is thereby conjoined thereto.
25		
	16	Said deformation may be accomplished by radial
	17	compression of the pipe wall or by circumferential
	18	stretching of the pipe wall, or by a combination of
30	19	such radial compression and circumferential stretching.
	20	Said direction may be purely circumferential, or said
	21	direction may be partly circumferential and partly
35	22	longitudinal.
00		
	23	The location where the pipes are intended to be
	24	conjoined may be remote from an accessible end of the
40	25	bore, and the conjoining method then comprises the
40	26	further steps of inserting the roller means into the
	27	accessible end of the bore (if the roller means is not
	28	already in the bore), and transferring the roller means
45	29	to the intended location. Transfer of the roller means
75	30	is preferably accomplished by the step of actuating
	31	traction means coupled to or forming part of the roller
	32	means and effective to apply along-bore traction forces
50		

5	-	6
	1	to the roller means by reaction against parts of the
	2	pipe bore adjacent the roller means.
10	3	The conjoining method according to the second aspect of
	4	the present invention can be applied to the mutual
	5	joining of successive lengths of casing or liner
	6	deployed in a well (e.g. a hydrocarbon exploration or
15	7	production well), such that conventional screw-threaded
	8	connectors are not required.
	9	According to third aspect of the present invention,
20	10	there is provided expansion apparatus for expanding a
	1.1	pipe or other hollow tubular article, said expansion
	12	apparatus comprising roller means constructed or
	13	adapted for rolling deployment against the bore of the
25	14	pipe, said roller means comprising at least one set of
20	15	individual rollers each mounted for rotation about a
	16	respective rotation axis which is generally parallel to
	17	the longitudinal axis of the apparatus, the rotation
30	18	axes of said at least one set of rollers being
30	19	circumferentially distributed around the expansion
	20	apparatus and each being radially offset from the
	21	longitudinal axis of the expansion apparatus, the
	22	expansion apparatus being selectively rotatable around
35	23	its longitudinal axis.
	24	The rotation axes of said at least one set of rollers
	25	may conform to a first regime in which each said
40	26	rotation axis is substantially parallel to the
	27	longitudinal axis of the expansion apparatus in a
	28	generally cylindrical configuration, or the rotation
	29	axes of said at least one set of rollers may conform to
45	30	a second regime in which each said rotation axis lies
	31	substantially in a respective radial plane including
	32	the longitudinal axis of the expansion apparatus and

5		7
	1	the rotation axes each converge substantially towards a
	2	common point substantially on the longitudinal axis of
	3	the expansion apparatus in a generally conical
10	4	configuration, or the rotation axes of said at least
	5	one set of rollers may conform to third regime in which
	6	each said rotation axis is similarly skewed with
	7	respect to the longitudinal axis of the expansion
15	8	apparatus in a generally helical configuration which
	9	may be non-convergent (cylindrical) or convergent
	10	(conical). Rollers in said first regime are
	11	particularly suited to profiling and finish expansion
20	12	of pipes and other hollow tubular articles, rollers in
	13	said second regime are particularly suited to
	14	commencing expansion in, and to flaring of pipes, and
	15	other hollow tubular articles, while rollers in said
25	16	third regime are suited to providing longitudinal
	17	traction in addition to such functions of the first or
	18	second regimes as are provided by other facets of the
	19	roller axes besides skew. The expansion apparatus may
30	20	have only a single such set of rollers, or the
	21	expansion apparatus may have a plurality of such sets
	22	of rollers which may conform to two or more of the
	23	aforesaid regimes of roller axis alignments; in a
35	24	particular example where the expansion apparatus has a
••	25	set of rollers conforming to the second regime located
	26	at leading end of the exemplary expansion apparatus and
	27	another set of rollers conforming to the first regime
40	28	located elsewhere on the exemplary expansion apparatus,
70	29	this exemplary expansion apparatus is particularly
	30	suited to expanding complete lengths of hollow tubular
	31	casing by reason of the conically disposed leading set
45	32	of rollers opening up previously unexpanded casing and
73	33	the following set of cylindrically disposed rollers
	34	finish-expanding the casing to its intended final
	35	diameter; if this exemplary expansion apparatus were

5		, 8
	1	modified by the addition of a further set of rollers
	2	conforming to third regime with non-convergent axes,
	3	this further set of rollers could be utilised for the
10	4	purpose of applying traction forces to the apparatus by
	5	means of the principles described in the present
	6	inventor's previously published PCT patent application
	7	WO93/24728-A1, the contents of which are incorporated
15	8	herein by reference.
•	9	The rollers of said expansion apparatus may each be
	10	mounted for rotation about its respective rotation axis
20	11	substantially without freedom of movement along its
20	12	respective rotation axis, or the rollers may each be
	13	mounted for rotation about its respective rotation axis
	14	with freedom of movement along its respective rotation
25	15	axis, preferably within predetermined limits of
	16	movement. In the latter case (freedom of along-axis
	17	movement within predetermined limits), this is
	18	advantageous in the particular case of rollers
30	19	conforming to the afore-mentioned second regime (i.e. a
	20	conical array of rollers) in that the effective maximum
	21	outside diameter of the rollers depends on the position
	22	of the rollers along the axis of the expansion
35	23	apparatus and this diameter is thereby effectively
	24	variable; this allows relief of radially outwardly
	<b>2</b> 5	directed forces by longitudinally retracting the
	26	expansion apparatus to allow the rollers collectively
40	27	to move longitudinally in the convergent direction and
	28	hence collectively to retract radially inwards away
	29	from the bore against which they were immediately
	30	previously pressing.
45	31	According to a fourth aspect of the present invention,
	32	there is provided profiling/conjoining apparatus for
	33	profiling or conjoining pipes or other hollow tubular
50		

5		9
	1	articles, said profiling/conjoining apparatus
	2	comprising roller means and radial urging means
	3	selectively operable to urge the roller means radially
10	4	outwards of a longitudinal axis of the
	5	profiling/conjoining apparatus, the radial urging means
	6	causing or allowing the roller means to move radially
	7	inwards towards the longitudinal axis of the
15	. 8	profiling/conjoining apparatus when the radial urging
	9	means is not operated, the roller means comprising a
	10	plurality of individual rollers each mounted for
	11	rotation about a respective rotation axis which is
20	12	substantially parallel to the longitudinal axis of the
	13	profiling/conjoining apparatus, the rotation axes of
	14	the individual rollers being circumferentially
	15	distributed around the apparatus and each said rotation
25	16	axis being radially offset from the longitudinal axis
	17	of the profiling/conjoining apparatus, the
	18	profiling/conjoining apparatus being selectively
	19	rotatable around its longitudinal axis to translate the
30	20	roller means across the bore of a pipe against which
	21	the roller means is being radially urged.
	22	
	23	The radial urging means may comprise a respective
35	24	piston on which each said roller is individually
	25	rotatably mounted, each said piston being slidably
	26	sealed in a respective radially extending bore formed
	27	in a body of the profiling/conjoining apparatus, a
40	28	radially inner end of each said bore being in fluid
70	29	communication with fluid pressure supply means
	30	selectively pressurisable to operate said radial urging
	31	means.
45	32	Alternatively, the radial urging means may comprise bi-
	33	conical race means upon which each said individual
	34	roller rolls in use of the profiling/conjoining
50		
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5		10
	1	apparatus, and separation variation means selectively
	2	operable controllably to vary the longitudinal
	3	separation of the two conical races of the bi-conical
10	4	race means whereby correspondingly to vary the radial
	5	displacement of each said roller rotation axis from th
	6	longitudinal axis of the profiling/conjoining
	7	apparatus. The separation variation means may compris
15	8	hydraulic linear motor means selectively pressurisable
	9	to drive one of said two cones longitudinally towards
	10	and/or away from the other said cone.
20	11	Embodiments of the invention will now be described by
	12	way of example, with reference to the accompanying
	13	drawings wherein :
25	14	Fig. 1 is a plan view of a first embodiment
	15	of profiling tool;
	16	Fig. 2 is an elevation of the profiling tool
30	17	of Fig. 1;
	18	Fig. 3 is a sectional perspective view of the
	19	profiling tool of Figs. 1 & 2, the section
35	20	being taken on the line III-III in Fig. 2;
3.0	21	Fig. 4 is an exploded perspective view of the
	22	profiling tool of Figs. 1-4;
40	23	Figs. 5A, 5B, & 5C are simplified sectional
40	24	views of three successive stages of operation
	25	of the profiling tool of Figs. 1-4;
	26	Fig. 6 is a schematic diagram illustrating
45	27	the metallurgical principle underlying the
	28	operational stage depicted in Fig. 5C;

	11
1	Figs. 7A & 7B are illustrations corresponding
2	to Figs. 5A & 5B but in respect of a variant
3	of the Figs. 1-4 profiling tool having two
10 4	rollers instead of three;
5	Figs. 8A & 8B are illustrations corresponding
6	to Figs. 5A & 5B but in respect of a variant
15 7	of the Figs. 1-4 profiling tool having five
8	rollers instead of three;
9	Figs. 9A & 93 respectively illustrate
20 10	starting and finishing stages of a first
11	practical application of the profiling tool
12	of Figs. 1-4;
25 13	Figs. 10A & 10B respectively illustrate
14	starting and finishing stages of a second
15	practical application of the profiling tool
16	of Figs. 1-4;
30	
17	Figs. 11A & 11B respectively illustrate
18	starting and finishing stages of a third
19	practical application of the profiling tool
35	of Figs. 1-4;
21	Figs. 12A & 12B respectively illustrate
22	starting and finishing stages of a fourth
40	practical application of the profiling tool
24	of Figs. 1-4;
25	Figs. 13A & 13B respectively illustrate
26 45	starting and finishing stages of a fifth
27	practical application of the profiling tool
28	of Figs. 1-4;

5	•	12
	1	Figs. 14A & 14B respectively illustrate
	2	starting and finishing stages of a sixth
	3	practical application of the profiling tool
10	4	of Figs. 1-4;
	5	Figs. 15A & 153 respectively illustrate
	6	starting and finishing stages of a seventh
15	7	practical application of the profiling tool
	8	cf Figs. 1-4;
	9	Figs. 16A & 16B respectively depict starting
20	10	and finishing stages of an eighth practical
20	11	application of the profiling tool of Figs. 1-
	12	4;
25	13	Figs. 17A & 17B respectively depict starting
	14	and finishing stages of a ninth practical
	15	application of the profiling tool of Figs. 1-
	16	4;
30		
	17	Fig. 18 schematically depicts a tenth
	18	practical application of the profiling tool
	19	of Figs. 1-4;
35		
	20	Fig. 19 schematically depicts an eleventh
	21 22	practical application of the profiling tool
	22	of Figs. 1-4;
40	23	Fig. 20 is a longitudinal elevation of a
	24	first embodiment of expansion tool in
	25	accordance with the present invention;
	26	
45	27	Fig. 21 is a longitudinal elevation, to an
	28	enlarged scale, of part of the expansion tool
	29	of Fig. 20;

5	-	13
	1	Fig. 21A is an exploded view of the tool part
	2	illustrated in Fig. 20;
10	3	Fig. 22 is a longitudinal section of the tool
	4	part illustrated in Fig. 20;
	5	Fig. 23 is a longitudinal section of the
15	6	expansion tool illustrated in Fig. 21;
	7	Fig. 24 is an exploded view of part of the
	8	expansion tool illustrated in Fig. 20;
20	_	
	9	Fig. 25 is a longitudinal section of an
	10	alternative form of the tool part illustrated
	11	in Fig. 21;
25		
	12	Fig. 26 is a longitudinal section of a
	13	technical variant of the tool part
	14	illustrated in Fig. 21;
30		
	15	Fig. 27 is a longitudinal elevation of a
	16	second embodiment of expansion tool in
	17	accordance with the present invention;
35		
	18	Figs. 28A, 28B, & 28C are respectively a
	19	longitudinal section, a longitudinal
	20	elevation, and a simplified end view of a
40	21	third embodiment of expansion tool in
	22	accordance with the present invention;
	23	Figs. 29A & 29B are longitudinal sections of
	24	a fourth embodiment of expansion tool in
45	25	accordance with the present invention,
	26	respectively in expanded and contracted
	27	configurations; and

5	•	14
	1	Fig. 30 is a longitudinal section of a fifth
	2	embodiment of expansion tool in accordance
	3	with the present invention.
10		•
	4	Referring first to Figs. 1 & 2, these depict a three-
	5	roller profiling tool 100 in accordance with the
	6	present invention. The tool 100 has a body 102 which
15	7	is hollow and generally tubular, with conventional
	8	screw-threaded end connectors 104 & 106 for connection
	9	to other components (not shown) of a downhole assembly.
	10	The end connectors 104 & 106 are of reduced diameter
20	11	(compared to the outside diameter of the longitudinally
	12	central body part 108 of the tool 100), and together
	13	with three longitudinal flutes 110 on the central body
	14	part 108, allow the passage of fluids along the outside
25	15	of the tool 100. The central body part 108 has three
	16	lands 112 defined between the three flutes 110, each
	17	land 112 being formed with a respective recess 114 to
	18	hold a respective roller 116 (see also Figs. 3 & 4).
30	19	Each of the recesses 114 has parallel sides and extends
	20.	radially from the radially perforated tubular core 115
	21	of the tool 100 to the exterior of the respective land
	22	112. Each of the mutually identical rollers 116 is
35	23	near-cylindrical and slightly barrelled (i.e. of sligh-
	24	tly greater diameter in its longitudinally central
	25	region than at either longitudinal end, with a
	26	generally convex profile having a discontinuity-free
40	27	transition between greatest and least diameters). Each
	28	of the rollers 116 is mounted by means of a bearing 118
	29	at each end of the respective roller for rotation about
	30	a respective rotation axis which is parallel to the
45	31	longitudinal axis of the tool 100 and radially offset
	32	therefrom at 120-degree mutual circumferential
	33	separations around the central part 108. The bearings
	34	118 are formed as integral end members of radially

5 slidable pistons 120, one piston 120 being slidably 2 sealed within each radially extending recess 114. The 3 inner end of each piston 120 is exposed to the pressure of fluid within the hollow core of the tool 100 by way 10 of the radial perforations in the tubular core 115; in use of the tool 100, this fluid pressure will be the downhole pressure of mud or other liquid within a drillstring or coiled tubing at or near the lower end 15 9 of which the toll 100 will be mounted. Thus by 10 suitably pressurising the core 115 of the tool 100, the pistons 120 can be driven radially outwards with a 11 controllable force which is proportional to the 12 20 13 pressurisation, and thereby the piston-mounted rollers 14 116 can be forced against a pipe bore in a manner to be detailed below. Conversely, when the pressurisation of 15 the core 115 of the tool 100 is reduced to below 16 25 17 whatever is the ambient pressure immediately outside 18 the tool 100, the pistons 120 (together with the 19 piston-mounted rollers 116) are allowed to retract radially back into their respective recesses 114. 20 30 21 (Such retraction can optionally be encouraged by 22 suitably disposed springs (not shown)). 23 The principles by which the profiling tool 100 35 24 functions will now be detailed with reference to Figs. 25 5 and 6. Fig. 5A is a schematic end view of the three rollers 26 27 116 within the bore of an inner pipe 180, the remainder 28 of the tool 100 being omitted for the sake of clarity. 29 The pipe 180 is nested within an outer pipe 190 whose 30 internal diameter is somewhat greater than the outside diameter of the inner pipe 180. As depicted in Fig. 31 32 5A, the core of the tool 100 has been pressurised just 33 sufficiently to push the pistons 120 radially outwards

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5		10
	1	and thereby to bring the piston-mounted rollers 116
	2	into contact with the bore of the inner pipe 180, but
	3	without at first exerting any significant forces on the
10	4	pipe 180.
	5	Fig. 5B depicts the next stage of operation of the
	6	profiling tool 100, in which the internal
15	7	pressurisation of the tool 100 is increased
15	8	sufficiently above its external pressure (i.e. the
	9	pressure in the region between the exterior of the tool
	10	100 and the bore of the pipe 180) such that the rollers
20	11	116 each exert a substantial outward force, as denoted
20	12	by the arrow-headed vectors superimposed on each roller
	13	116 in Fig. 5B. The effect of such outward forces on
	14	the rollers 116 is circumferentially to deform the wall
05	15	of the inner pipe 180 (with concomitant distortion of
25	16	the pipe 180 which is shown in Fig. 53 for the sake of
	17	clarity). When the roller-extended lobes touch the
	18	bore of the outer pipe 190, the inner pipe 180 is
30	19	thereby anchored against rotation with respect to the
30	20	outer pipe 190, or at least constrained against free
	21	relative rotation. By simultaneously rotating the
	22	tool 100 around its longitudinal axis (which will
35	23	normally be substantially coincident with the
33	24	longitudinal axis of the pipe 180), the circumferential
	25	deformation of the wall of the pipe 180 tends to become
	26	uniform around the pipe 180, and the pipe 180
40	27	circumferentially extends into substantially uniform
40	28	contact with the bore of the outer pipe 190, as
	29	depicted in Fig. 5C. This occurs due to the rollers
	30	causing rolling compressive yield of the inner pipe
400	31	wall to cause reduction in wall thickness, increase in
45	32	circumference and consequent increase in diameter.
	33	(Rotation of the tool 100 can be undertaken by any
	34	suitable procedure, several of which will subsequently

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5	•	17
	1	be described). Circumferential deformation of the pipe
	2	180 is initially elastic and may subsequently be
	3	plastic. A secondary effect of the process is to
10	4	generate compressive hoop stress in the internal
	5	portion of the inner tube and an interference fit
	6	between the inner tube and the outer tube.
15	7	From the stage depicted in Fig. 5C wherein the inner
	В	pipe 180 has initially been circumferentially deformed
	9	just into full contact with the bore of the outer pipe
	10	190 (thus removing the previous clearance between the
20	11	pipes 180 and 190) but without stretching or distortion
	12	of the outer pipe 190, continued (and possibly
	13	increased) internal pressurisation of the tool 100 in
	14	conjunction with continued rotation of the tool 100 (at
25	15	the same rotational speed or at a suitably different
	16	rotational speed) forces the inner pipe 180 outwards
	17	against the resistance to deformation of the outer pipe
	18	190. Since the inner pipe 180 is now backed by the
30	19	outer pipe 190 with respect to the radially outward
30	20	forces being applied by the rollers 116 such that the
	21	wall of the inner pipe 180 is now pinched between the
	22	rollers 116 and the outer pipe 190, the mechanism of
35	23	deformation of the pipe 180 changes to compressive
35	24	extension by rolling (i.e. the same thinning/extension
	25	principle as prevails in conventional steel rolling
	26	mills, as schematically depicted in Fig. 6 wherein the
	27	circular rolling of Figs. 5A-5C has been opened out and
40	28	developed into an equivalent straight-line rolling
	29	procedure to enhance the analogy with steel rolling
	30	mills).
45	31	When operation of the tool 100 is terminated and the
	32	rollers 116 are caused or allowed to retract radially
	33	into the body of the tool 100 thereby to relieve the
50		

5	•	18
	1	pipes 180 of all contact with the rollers 116, the
	2	induced compressive hoop stress created in the wall of
	3	the inner pipe 180 due to the rolling process causes
10	4	the inner pipe 180 to remain in contact with the inner
	5	wall of the outer pipe 190 with very high contact
	6	stresses at their interface.
15	7	Figs. 7A & 7B correspond to Figs. 5A & 5B, and
	8	schematically depict the equivalent stages of operation
	9	of a two-roller profiling tool (not otherwise shown per
	10	se) in order to illustrate the effects of using a
20	11	profiling tool having fewer than the three rollers of
	12	the profiling tool 100 detailed above.
	13	Figs. 8A & 8B also correspond to Figs. 5A & 5B, and
25	14	schematically depict the equivalent stages of operation
	15	of a five-roller profiling tool (not otherwise shown
	16	per se) in order to illustrate the effects of using a
	17	profiling tool having more than the three rollers of
30	18	the profiling tool 100 detailed above.
	19	It should be noted that though the very high contact
	20	stresses existing at the interface of the inner pipe
	21	180 and outer pipe 190 may cause the outer pipe 190 to
35	22	expand elastically or plastically, it is not a
	23	requirement of this process that the outer pipe 190 is
	24	capable of any expansion whatsoever. The process would
	25	still result in the high contact stresses between the
40	26	inner pipe 180 and the outer pipe 190 even if the outer
	27	pipe 190 was incapable of expansion, eg by being thick
	28	walled, by being encased in cement, or being tightly
	29	embedded in a rock formation.
45		
	30	Various practical applications of profiling tools in
	31	accordance with the invention will now be described
50		

5	•	19
	1	with reference to Figs. 9 - 19. The profiling tool
	2	used in these practical applications may be the
	3	profiling tool 100 detailed above, or some variant of
10	4	such a profiling tool which differs in one or more
	5	details without departing from the scope of the
	6	invention.
15	7	Fig. 9A schematically depicts the upper end of a first
	8	pipe or casing 200 concentrically nested within the
	9	lower end of a second pipe or casing 202 whose bore
	10	(internal diameter) is marginally greater than the
20	11	outside diameter of the first pipe or casing 200. A
	12	profiling tool (not shown) is located within the upper
	13	end of the first pipe or casing 200 where it is
	14	overlapped by the second pipe or casing 202. The
25	15	rollers of the profiling tool are then radially
	16	extended into contact with the bore of the inner pipe
	17	or casing 200 by means of internal pressurisation of
	18	the profiling tool (or by any other suitable means
30	19	which may alternatively be utilised for forcing the
<b>J</b> 0	20	rollers radially outwards of the profiling tool). The
	21	outward forces exerted by the rollers on the bore of
	22	the first pipe or casing 200 are schematically depicted
35	23	by the force-vector-depicting arrows 204.
	24	From the starting situation depicted in Fig. 9A,
	25	combined with suitable rotation of the profiling tool
	26	about its longitudinal axis (which is substantially
40	27	coincident with the longitudinal axis of the first pipe
	28	or casing 200), the finish situation schematically
	29	depicted in Fig. 9B is arrived at, namely the upper end
	30	of the inner pipe or casing 200 is profiled by
45	31	permanent plastic expansion into conjunction with the
	32	lower end of the second pipe or casing 202. Thereby
•	33	the two pipes or casings are permanently conjoined

5	•	20
-	1	without the use of any form of separate connector and
	2	without the use of conventional joining techniques such
	3	as welding.
10		3
,,	4	Figs. 10A & 10B correspond to Figs. 9A & 9B
	5	respectively, and schematically illustrate an optional
	6	modification of the profiling/conjoining technique
15	7	described with respect to Figs. 9A & 9B. The
15	8	modification consists of applying an adherent coating
	9	206 cf hard particulate material to the exterior of the
	10	upper end of the first (inner) pipe or casing 200 prior
20	11	to its location within the lower end of the second
20	12	(outer) pipe or casing 202. The hard particulate
	13	material may consist of carbide granules, e.g. tungsten
	14	carbide granules such as are commonly used to coat
0.5	15	downhole reamers. In the application depicted in Figs.
25	16	10A & 10B, the hard particulate material is selected
	17	for its crush resistance rather than for its abrasive
	18	qualities, and in particular the material is selected
	19	for its ability to interpenetrate the meeting surfaces
30	20	of two sheets of steel which are pressed together with
	21	the hard particulate material sandwiched between the
	22	steel components. Such sandwiching is schematically
	23	depicted in Fig. 10B. Tests have shown a surprising
35	24	increase in resistance to separation forces of pipes or
	25	other articles conjoined by a profiling tool in
	26	accordance with the invention to withstand, where a
	27	coating of hard particulate material was first
40	28	interposed between the parts being conjoined. It is
	29	preferred that of the whole area to be coated, only a
	30	minority of the area is actually covered with the
	31	particulate material, e.g. 10% of the area. (It is
45	32	believed that a higher covering factor actually reduces
	33	the interpenetration effect and hence diminishes the
	34	benefits below the optimum level).

5		21
	1	Referring now to Figs. 11A & 11B, these schematically
	2	depict an optional modification of the Fig. 9
	3	conjoining procedure to achieve improved sealing
10	4	between the two conjoined pipes or casings. As
	5	depicted in Fig. 11A, the modification comprises
	6	initially fitting the exterior of the first (inner)
	7	pipe or casing 200 with a circumferentially extending
15	8	and part-recessed ductile metal ring 208, which may
	9	(for example) be formed of a suitable copper alloy or a
	10	suitable tin/lead alloy. The modification also
	11	comprises initially fitting the exterior of the first
20	12	(inner) pipe or casing 200 with a circumferentially
20	13	extending and fully recessed elastomeric ring 210. As
	14	depicted in Fig. 11B, the rings 208 and 210 become
	15	crushed between the two pipes or casings 200 & 202
25	16	after these have been conjoined by the profiling tool,
25	17	and thereby a mutual sealing is achieved which may be
	18	expected to be superior to the basic Fig. 9 arrangement
	19	in otherwise equal circumstances. In suitable
20	20	situations, one or other of the sealing rings 208 and
30	21	210 may be omitted or multiplied to achieve a necessary
	22	or desirable level of sealing (e.g. as in Fig. 12).
	23	Referring now to Figs. 12A & 12B, these schematically
35	24	depict an arrangement in which the lower end cf the
	25	second (outer) casing 202 is pre-formed to have a
	26	reduced diameter so as to function as a casing hanger.
	27	The upper end of the first (inner) casing 200 is
40	28	correspondingly pre-formed to have an increased
	29	diameter which is complementary to the reduced diameter
	30	of the casing hanger formed at the lower end of the
	31	outer casing 202, as depicted in Fig. 12A. Optionally,
45	32	the upper end of the first (inner) casing 200 may be
	33	provided with an external seal in the form of an
	34	elastomeric ring 212 flush-mounted in a circumferential

5		22
	1	groove formed in the outer surface of the first casing
	2	200. The arrangement of Fig. 12A differs from the
	3	arrangement of Fig. 9A in that the latter arrangement
10	4	requires the pipe or casing 200 to be positively held
	5	up (to avoid dropping down the well out of its intended
	6	position) until joined to the upper pipe or casing as
	7	in Fig. 9B, whereas in the Fig. 12A arrangement the
15	8	casing hanger allows the inner/lower casing 200 to be
	9	lowered into position and then released without the
	10	possibility of dropping out of position prior to the
	11	two casings being conjoined by the profiling tool, as
20	12	depicted in Fig. 12B.
20		
	13	Referring now to Figs. 13A & 13B, these schematically
	14	depict another optional modification of the Fig. 9
25	15	conjoining procedure in order to achieve a superior
••	16	resistance to post-conjunction separation. As depicted
	17	in Fig. 13A, the modification consists of initially
	18	forming the bore (inner surface) of the second (outer)
30	19	pipe or casing 202 with two circumferentially extending
30	20	grooves 214 each having a width which reduces with
	21	increasing depth. As depicted in Fig. 13B, when the
	22	two pipes or casings 200 and 202 have been conjoined by
35	23	the profiling tool (as detailed with respect to Figs.
33	24	9A & 9B), the first (inner) pipe or casing 200 will
	25	have been plastically deformed into the grooves 214,
	26	thereby increasing the interlocking of the conjoined
40	27	pipes or casings and extending their resistance to
40	28	post-conjunction separation. While two grooves 214 are
	29	shown in Pigs. 13A & 13B by way of example, this
	30	procedure can in suitable circumstances be carried with
	31	one such groove, or with three or more such grooves.
45	32	While each of the grooves 214 has been shown with a
	33	preferred trapezoidal cross-section, other suitable
	34	groove cross-sections can be substituted.

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5		23
	1	The superior joint strength of the Fig. 13 arrangement
	2	can be combined with the superior sealing function of
	3	the Fig. 11 arrangement, as shown in Fig. 14. Fig. 14
10	4	schematically depicts the pre-jointing configuration,
	5	in which the exterior of the first (inner) pipe or
	6	casing 200 is fitted with a longitudinally spaced pair
	7	of circumferentially extending and part-recessed
15	8	ductile metal rings 208, while the bore (inner surface)
,,	9	of the second (outer) pipe or casing 202 is formed with
	10	two circumferentially extending grooves 214 each having
	11	a width which reduces with increasing depth. The
20	12	longitudinal spacing of the two grooves 214 is
20	13	substantially the same as the longitudinal spacing of
	14	the seal rings 208. When the two pipes or casings are
	15	conjoined by use of the profiling tool (as
	16	schematically depicted in Fig. 14B), the first (inner)
25	17	pipe or casing 200 is not only plastically deformed
	18	into the corresponding grooves 214 (as in Fig. 13B),
	19	but the metal rings 208 are crushed into the bottoms of
	20	these grooves 214 thereby to form high grade metal-to-
30	21	metal seals.
	22	In the arrangements of Figs. 9 - 14, it is assumed that
	23	the second (outer) pipe or casing 202 undergoes little
35	24	or no permanent deformation, which may either be due to
	25	the outer pipe or casing 202 being inherently rigid
	26	compared to the first (inner) pipe or casing 200, or be
	27	due to the outer pipe or casing being rigidly backed
40	28	(e.g. by cured concrete filling the annulus around the
	29	outer pipe or casing 202), or be due to a combination
	30	of these and/or other reasons. Fig. 15 schematically
	31	depicts an alternative situation in which the second
45	32	(outer) pipe or casing 202 does not have the previously
	33	assumed rigidity. As schematically depicted in Fig.
	34	15A, the pre-jointing configuration is merely a variant
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5		24
	1	of the previously described pipe-joining arrangements,
	2	in which the exterior of the upper end of the first
	3	(inner) pipe or casing 200 is provided with two part-
10	4	recessed metal seal rings 208 (each mounted in a
	5	respective circumferential groove), neither pipe being
	6	otherwise modified from its initial plain tubular
	7	shape. To conjoin the casings 200 and 202, the
15	8	profiling tool is operated in a manner which forces the
	9	second (outer) casing 202 through its elastic limit and
	10	into a region of plastic deformation, such that when
	11	the conjoining process is completed, both casings
20	12	retain a permanent outward set as depicted in Fig. 15B.
	13	In each of the arrangements described with reference to
	14	Figs. 9 - 15, the bore of the first pipe or casing 200
25	15	was generally smaller than the bore of the second pipe
	16	or casing 202. However, there are situations where it
	17	would be necessary or desirable that these bores be
	18	about mutually equal following conjoining, and this
30	19	requires variation of the previously described
	20	arrangements, as will now be detailed.
	21	In the arrangement schematically depicted in Fig. 16A,
35	22	the lower end of the second (outer) pipe or casing 202
•	23	is pre-formed to have an enlarged diameter, the bore
	24	(inside diameter) of this enlarged end being marginally
	25	greater than the outside diameter of the first (inner)
40	26	pipe or casing 200 intended to be conjoined thereto.
,0	27	The first (inner) pipe or casing 200 has initial
	28	dimensions which are similar or identical to those of
	29	the second pipe or casing 202 (other than for the
45	30	enlarged end of the pipe or casing 202). Following use
70	31	of the profiling tool to expand the overlapping ends of
	32	the two pipes or casings, both bores have about the
	33	same diameter (as depicted in Fig. 16B) which has

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	1	certain advantages (e.g. a certain minimum bore at
	2	depth in a well no longer requires a larger or much
	3	larger bore at lesser depth in the well). While
10	4	surface-level pipes can be extended in this manner
	5	without difficulties in adding extra lengths of pipe,
	6	special techniques may be necessary for feeding
	7	successive lengths of casing to downhole locations when
15	8	extending casing in a downhole direction. (One
	9	possible solution to this requirement may be provide
	10	successive lengths of casing with a reduced diameter,
	11	and to expand the entire length of each successive
20	12	length of casing to the uniform bore of previously
	13	installed casing, this being achievable by further
	14	aspects of the invention to be subsequently described
	15	by way of example with reference to Figs. 20 et seq).
25		
	16	A modification of the procedure and arrangement of Fig.
	17	16 is schematically depicted in Fig. 17 wherein the end
	18	of the outer pipe or casing is not pre-formed to an
30	19	enlarged diameter (Fig. 17A). It is assumed in this
	20	case that the profiling tool is capable of exerting
	21	sufficient outward force through its rollers as to be
	22	capable of sufficiently extending the diameter of the
35	23	outer pipe or casing simultaneously with the diametral
35	24	extension of the inner pipe or casing during forming of
	25	the joint (Fig. 17B).
	26	As well as conjoining pipes or casings, the profiling
40	27	tool in accordance with the invention can be utilised
	28	for other useful purposes such as will now be detailed
	29	with reference to Pigs. 18 and 19.
45	30	In the situation schematically depicted in Fig. 18, a
	31	riser 220 has a branch 222 which is to be blocked off

while continuing to allow free flow of fluid along the

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	1	riser 220. To meet this requirement, a sleeve 224 is
	2	placed within the riser 220 in position to bridge the
	3	branch 222. The sleeve 224 initially has an external
10	4	diameter which is just sufficiently less than the
	5	internal diameter of the riser 220 as to allow the
	6	sleeve 224 to be passed along the riser to its required
	7	location. Each end of the sleeve 224 is provided with
15	8	external seals 226 of any suitable form, e.g. the seals
	9	described with reference to Fig. 11. When the sleeve
	10	224 is correctly located across the branch 222, a
	11	profiling tool (not shown in Fig. 18) is applied to
20	12	each end of the sleeve 224 to expand the sleeve ends
	13	into mechanically anchoring and fluid-sealing contact
	14	with the bore of the riser 220, thus permanently
	15	sealing the branch (until such time as the sleeve may
25	16	be milled away or a window may be cut through it).
	17	Fig. 19 schematically depicts another alternative use
	18	of the profiling tool in accordance with the invention,
30	19	in which a valve requires to be installed within plain
30	20	pipe or casing 240 (i.e. pipe or casing free of landing
	21	nipples or other means of locating and anchoring
	22	downhole equipment). A valve 242 of a size to fit
35	23	within the pipe or casing 240 has a hollow tubular
33	24	sleeve 244 welded or otherwise secured to one end of
	25	the valve. The sleeve 244 initially has an external
	26	diameter which is just sufficiently less than the
	27	internal diameter of the pipe or casing 240 as to allow
40	28	the mutually attached valve 242 and sleeve 244 to
	29	passed down the pipe or casing 240 to the required
	30	location. The end of the sleeve 244 opposite to the
	31	end attached to the valve 242 is provided with external
45	32	seals 246 of any suitable form, e.g. the seals
	33	described with reference to Fig. 11. When the valve
	34	242 is correctly located where it is intended to be

5		27
	1	installed, a profiling tool (not shown in Fig. 19) is
	2	applied to the end of the sleeve opposite the valve 242
	3	to expand that end of the sleeve 244 into mechanically
10	4	anchoring and fluid-sealing contact with the bore of
	5	the pipe cr casing 240. An optional modification of
	6	the Fig. 19 arrangement is to attach an expandable
	7	sleeve to both sides of the valve such that the valve
15	8	can be anchored and sealed on either side instead of
	9	one side only as in Fig. 19.
	10	Turning now to Fig. 20, this illustrates a side
20	11	elevation of an embodiment of expansion tool 300 in
	12	accordance with the present invention. The expansion
	13	tool 300 is an assembly of a primary expansion tool 302
	14	and a secondary expansion tool 304, together with a
25	15	connector sub 306 which is not essential to the
	16	invention but which facilitates mechanical and
	17	hydraulic coupling of the expansion tool 300 to the
	18	downhole end of a drillstring (not shown) or to the
30	19	downhole end of coiled tubing (not shown). The primary
	20	expansion tool 302 is shown separately and to an
	21	enlarged scale in Fig. 21 (and again, in exploded view,
	22	in Fig. 21A). The expansion tool 300 is shown in
35	23	longitudinal section in Fig. 22, the primary expansion
	24	tool 302 is shown separately in longitudinal section in
	25	Fig. 23, and the secondary expansion tool 304 is shown
	26	separately in an exploded view in Fig. 24.
40	27	From Figs. 20 - 24 it will be seen that the general
	28	form of the primary expansion tool 302 is that of a
	29	roller tool externally presenting a conical array of
	30	four tapered rollers 310 tapering towards an imaginary
45	31	point (not denoted) ahead of the leading end of the
	32	expansion tool 300, i.e. the right end of the tool 300
	33	as viewed in Figs. 20 & 21. As may be more clearly
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5		28
	1	seen in Figs. 21A, 22, & 23, the rollers 310 run on a
	2	conical race 312 integrally formed on the surface of
	3	the body of the primary expansion tool 302, the rollers
10	4	310 being constrained for true tracking by a
	5	longitudinally slotted cage 314. An end retainer 316
	6	for the rollers 310 is secured on the screw-threaded
	7	leading end 318 of the primary expansion tool 302 by
15	8	means of a ring nut 320. The trailing end 322 of the
	9	primary expansion tool 302 is screw-threaded into the
	10	leading end 106 of the secondary expansion tool 304 to
	11	form the composite expansion tool 300. Functioning of
20	12	the primary expansion tool 300 will be detailed
	13	subsequently.
	14	The secondary expansion tool 304 is substantially
25	15	identical to the previously detailed profiling tool 100
	16	(except for one important difference which is described
	17	below), and accordingly those parts of the secondary
	18	expansion tool 304 which are the same as corresponding
30	19	parts of the profiling tool 100 (cr which are obvious
	20	modifications thereof) are given the same reference
	21	numerals. The important difference in the secondary
	22	expansion tool 304 with respect to the profiling tool
35	23	100 is that the rotation axes of the rollers 116 are no
35	24	longer exactly parallel to the longitudinal axis of the
	25	tool, but are skewed such that each individual roller
	26	rotation axis is tangential to a respective imaginary
	27	helix, though making only a small angle with respect to
40	28	the longitudinal direction (compare Fig. 24 with Fig.
	29	4). As particularly shown in Figs. 20 and 24, the
	30	direction (or "hand") of the skew of the rollers 116 in
45	31	the secondary expansion tool 304 is such that the
	32	conventional clockwise rotation of the tool (as viewed
	33	from the uphole end of the tool, i.e. the left end as
	34	viewed in Figs. 20 & 22) is such as to induce a

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	1	reaction against the bore of the casing (not shown in
	2	Figs. 20 - 24) which tends not only to rotate the tool
	3	300 around its longitudinal axis but also to advance
10	4	the tool 300 in a longitudinal direction, i.e. to drive
	5	the tool 300 rightwards as viewed in Figs. 20 & 22.
	6	(The use of skewed bore-contacting rollers to cause a
	7	rotating downhole tool to drive itself along a casing
15	8	is detailed in the afore-mentioned WO93/24728-A1).
	9	In use of the expansion tool 300 to expand casing (not
	10	shown) previously deployed to a selected downhole
20	11	location in a well, the tool 300 is lowered on a
	12	drillstring (not shown) or coiled tubing (not shown)
	13	until the primary expansion tool 302 at the leading end
	14	of the tool 300 engages the uphole end of the
25	15	unexpanded casing. The core of the tool 300 is
20	16	pressurised to force the roller-carrying pistons 120
	17	radially outwards and hence to force the rollers 116
	18	into firm contact with the casing bore. The tool 300
30	19	is simultaneously caused to rotate clockwise (as viewed
30	20	from its uphole end) by any suitable means (e.g. by
	21	rotating the drillstring (if used), or by actuating a
	22	downhole mud motor (not shown) through which the tool
35	23	300 is coupled to the drillstring or coiled tubing),
33	24	and this rotation combines with the skew of the rollers
	25	116 of the secondary tool 304 to drive the tool 300 as
	26	a whole in the downhole direction. The conical array
40	27	of rollers 310 in the primary expansion tool 302 forces
40	28	its way into the uphole end of the unexpanded casing
	29	where the combination of thrust (in a downhole
45	30	direction) and rotation rolls the casing into a conical
	31	shape that expands until its inside diameter is just
	32	greater than the maximum diameter of the array of
	33	rollers 310 (i.e. the circumscribing diameter of the
	34	array of rollers 310 at its upstream end). Thereby the

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	1	primary expansion tool 302 functions to bring about the
	2	primary or initial expansion of the casing.
10	3	The secondary expansion tool 304 (which is immediately
	4	uphole of the primary expansion tool 302) is internally
	5	pressurised to a pressure which not only ensures that
	6	the rollers 116 contact the casing bore with sufficient
15	7	force as to enable the longitudinal traction force to
	8	be generated by rotation of the tool about its
	9	longitudinal axis but also forces the pistons 120
	10	radially outwards to an extent that positions the
20	11	piston-carried rollers 116 sufficiently radially
	12	distant from the longitudinal axis of the tool 304
	13	(substantially coincident with the centreline of the
	. 14	casing) as to complete the diametral expansion of the
25	15	casing to the intended final diameter of the casing.
	16	Thereby the secondary expansion tool 304 functions to
	17	bring about the secondary expansion of the casing.
	18	(This secondary expansion will normally be the final
30	19	expansion of the casing, but if further expansion of
	20	the casing is necessary or desirable, the expansion
	21	tool 300 can be driven through the casing again with
	22	the rollers 116 of the secondary expansion tool set at
35	23	a greater radial distance from the longitudinal axis of
35	24	the tool 304, or a larger expansion tool can be driven
	25	through the casing). While the primary expansion tool
	26	302 with its conical array of rollers 310 is preferred
40	27	for initial expansion of casing, the secondary
40	28	expansion tool 304 with its radially adjustable rollers
	29	has the advantage that the final diameter to which the
45	30	casing is expanded can be selected within a range of
	31	diameters. Moreover, this final diameter can not only
	32	be adjusted while the tool 304 is static but can also
	33	be adjusted during operation of the tool by suitable
	34	adjustment of the extent to which the interior of the
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	1	tool 304 is pressurised above the pressure around the
	2	outside of the tool 304. This feature also gives the
	3	necessary compliance to deal with variances in wall
10	4	thickness
	5	Fig. 25 is a longitudinal section of a primary
	6	expansion tool 402 which is a modified version of the
15	7	primary expansion tool 302 (detailed above with
	8	reference to Figs. 20 - 24). Components of the tool
	9	402 which correspond to components of the tool 302 are
	10	given the same reference numeral except that the
20	11	leading "3" is replaced by a leading "4". The tool 402
20	12	is essentially the same as the tool 302 except that the
	13	rollers 410 are longer than the rollers 310, and the
	14	conical race 412 has a cone angle which is less than
25	15	the cone angle of the race 312 (i.e. the race 412
25	16	tapers less and is more nearly cylindrical than the
	17	race 312). As shown in Fig. 25, the trailing (uphole)
	18	end of the tool 402 is broken away. For details of
20	19	other parts of the tool 402, reference should be made
30	20	to the foregoing description of the tool 302. In
	21	contrast to Figs. 20 - 24, Fig. 25 also shows a
	22	fragment of casing 480 which is undergoing expansion by
	23	the tool 402.
35		
	24	Fig. 26 is a longitudinal section of a primary
	25	expansion tool 502 which is a further-modified version
	26	of the primary expansion tool 302. Components of the
40	27	tool 502 which correspond to components of the tool 302
	28	are given the same reference numeral except that the
	29	leading "3" is replaced by a leading "5". The tool 502
	30	is identical to the tool 402 except that the rollers
45	31	510 have a length which is somewhat less than the
	32	length of the rollers 410. This reduced length allows
	33	the rollers 510 some longitudinal freedom within their

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	ı	windows in the cage 514. Consequently, although
	2	expansion operation of the primary expansion tool 502
	3	is essentially identical to operation of the primary
10	4	expansion tool 410 (and similar to operation of the
	5	primary expansion tool 310 except for functional
	6	variations occasioned by the different conicities of
	7	the respective races), reversal of longitudinal thrust
15	8	on the tool 502 (i.e. pulling the tool 502 uphole
	9	instead of pushing the tool 502 downhole) will cause or
	10	allow the rollers 510 to slide along the conical race
	11	512 in the direction of its reducing diameter, thus
20	12	allowing the rollers 510 radially to retract from the
	13	casing bore as illustrated in Fig. 26. Such roller
	14	retraction frees the tool 502 from the casing 480 and
	15	permits free withdrawal of the tool 502 in an uphole
25	16	direction whereas the non-retracting rollers 410 of the
	17	tool 402 might possibly jam the tool 402 within the
	18	casing 480 in the event of attempted withdrawal of the
	19	tool 402.
30		
,	20	Turning now to Fig. 27, this is a simplified
	21	longitudinal elevation of a casing expander assembly
	22	600 for use in downhole expansion of a solid, slotted
35	23	or imperforate metal tube 602 within a casing 604 which
55	24	lines a well. The casing expander assembly 600 is a
	25	three-stage expansion tool which is generally similar
	26	(apart from the number of expansion stages) to the two-
40	27	stage expansion tool 300 described above with reference
70	28	to Figs. 20 - 24.
	29	In order from its leading (downhole) end, the expander
45	30	assembly 600 comprises a running/guide assembly 610, a
	31	first-stage conical expander 612, an inter-stage
	32	coupling 614, a second-stage conical expander 616, a
	33	further inter-stage coupling 618, and a third-stage
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	1	cylindrical expander 620.
10	2	The first-stage conical expander 612 comprises a
	3	conical array of tapered rollers which may be the same
	4	as either one of the primary expansion tools 302 or
	5	402, or which differs therefrom in respect of the
	6	number of rollers and/or in respect of the cone angles
15	7	of the rollers and their race.
	8	The second-stage conical expander 616 is an enlarged-
	9	diameter version of the first-stage conical expander
20	10	612 dimensioned to provide the intermediate expansion
	11	stage of the three-stage expansion assembly 600. The
	12	diameter of the leading (narrow) end of the second-
	13	stage expander 616 (the lower end of the expander 616
25	14	as viewed in Fig. 27) is marginally less than the
	15	diameter of the trailing (wide) end of the first-stage
	16	expander 612 (the upper end of the expander 612 as
	17	viewed in Fig. 27) such that the second-stage expander
30	18	616 is not precluded from entering initially expanded
	19	tube 602 resulting from operation of the first-stage
	20	expander 612.
35	21	The third-stage expander 620 is a generally cylindrica
3.7	22	expander which may be similar either to the profiling
	23	tool 100 or to the secondary expansion tool 304.
	24	(Although the rollers of the third-stage expander 620
40	25	may be termed "cylindrical" in order to facilitate
40	26	distinction over the conical rollers of the first-stag
	27	and second-stage expanders 612 & 616, and although in
	28	certain circumstances such so-called "cylindrical"
45	29	rollers may in fact be truly cylindrical, the rollers
45	30	of the cylindrical expander will usually be barrelled
	31	to avoid excessive end stresses). The rollers of the

third-stage expander 620 will normally be radially

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•	1	extended from the body of the expander 620 by an extent
	2	that the third-stage expander 620 rolls the tube 602
	3	into its final extension against the inside of casing
10	4	604, such that no further expansion of the tube 602 is
10	5	required in the short term.
	,	required in the short term.
	6	The inter-stage couplings 614 and 618 can be
15	7	constituted by any suitable arrangement that
	8	mechanically couples the three expander stages, and
	9	(where necessary or desirable) also hydraulically
	10	couples the stages.
20		
	11	The rollers of the third-stage expander 620 may be
	12	skewed such that rotation of the assembly 600 drives
	13	the assembly in a downhole direction; alternatively,
25	14	the rollers may be unskewed and forward thrust on the
	15	expanders be provided by suitable weights, e.g. by
	16	drill collars 630 immediately above the assembly 600.
	17	Where the third-stage rollers are skewed, drill collars
30	18	can be employed to augment the downhole thrust provided
	19	by rotation of the assembly 600.
	20	As depicted in Fig. 27, the three-stage expander
35	21	assembly 600 is suspended from a drillstring 640 which
33	22	not only serves for transmitting rotation to the
	23	assembly 600 but also serves for transmitting hydraulic
	24	fluid under pressure to the assembly 600 for radial
40	25	extension of the third-stage rollers, for cooling the
40	26	assembly 600 and newly deformed tube 602, and for
	27	flushing debris out of the work region.
	28	In suitable circumstances, the drillstring 540 may be
45	29	substituted by coiled tubing (not shown) of a form
	30	known per se.

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35 Turning now to Pig. 28 (which is divided into three 1 2 mutually related Figs. 28A, 28B, & 28C), these 3 illustrate a primary expansion tool 702 which may be summarised as being the primary expansion tool 402 10 5 (Fig. 25) with hard steel bearing balls 710 substituted for the rollers 410. Each of the balls 710 runs in a 6 7 respective circumferential groove 712, and is located 8 for proper tracking by a suitably perforated cage 714. 15 9 As with the tool 402, the cage 714 is retained by a retainer 716 secured on the screw-threaded leading end 10 11 718 of the tool 702 by means of a ring nut 720. 12 Operation of the tool 702 is functionally similar to 20 13 operation of the tool 402, as is illustrated by the 14 expansion effect of the tool 702 on casing 480. 15 The primary expansion tool 702 as shown in Figs. 28A -25 28C could be modified by the substitution of the series 16 17 of circumferential ball tracks 712 with a single spiral 18 track (not shown) around which the balls 710 would 19 circulate at ever-increasing radii to create the 30 20 requisite expansion forces on the casing. At the point of maximum radius, the balls 710 would be recirculated 21 22 back to the point of minimum radius (near the leading 23 end of the tool 702, adjacent the retainer 716) by 35 means of a channel (not shown) formed entirely within 24 25 the central body of the tool 702 in a form analogous to 26 a recirculating ball-screw (known per se). 40 27 Figs. 29A & 29B illustrate a modification 802 of the ball-type expansion primary expansion tool 702 of Fig. 28 29 28 analogous to the Fig. 26 modification 502 of the 30 Fig. 25 roller-type primary expansion tool 402. In the 45 modified ball-type primary expansion tool 802, the hard 31 32 steel bearing balls 810 run in longitudinally-extending 33 grooves 812 instead of the circumferential grooves 712

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	1	of the tool 702. The ball-guiding perforations in the
	2	cage 814 are longitudinally extended into slots which
	3	allow individual balls 810 to take up different
10	4	longitudinal positions (and hence different effective
	5	radii) according to whether the tool 802 is being
	6	pushed downhole (Fig. 28A) or being pulled uphole (Fig.
	7	28B). In the latter case, the balls 810 are relieved
15	8	from pressure on the surrounding casing 480 and thereby
	9	obviate any risk of the tool 802 becoming jammed in
	10	partly-expanded casing.
20	11	In the profiling and expansion tools with controllably
	12	displaceable rollers as previously described, e.g. with
	13	reference to Figs. 4 and 24, the ability to obtain and
	14	to utilise hydraulic pressure may place practical
25	15	limits on the forces which can be exerted by the
	16	rollers. Fig. 30 illustrates a roller-type
	17	expansion/profiling tool 900 which utilises a
	18	mechanical force-multiplying mechanism to magnify a
30	19	force initially produced by controlled hydraulic
30	20	pressure, and to apply the magnified force to
	21	profiling/expanding rollers 902. Each of the plurality
	22	of rollers 902 (only two being visible in Fig. 30) has
35	23	a longitudinally central portion which is near-
33	24	cylindrical and slightly barrelled (i.e. slightly
	25	convex), bounded on either side by end portions which
	26	are conical, both end portions tapering from
	27	conjunction with the central portion to a minimum
40	28	diameter at each end. Rotation of each roller 902
	29	about a respective rotation axis which is parallel to
	30	the longitudinal axis of the tool 900 and at a
	31	controllably variable radial displacement therefrom is
45	32	ensured by a roller-guiding cage 904 of suitable form.
	33	The effective working diameter of the tool 900 is

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•	1	dependent on the (normally equal) radial displacements
	2	of the rollers 902 from the longitudinal axis of the
10	3	tool 900 (such displacement being shown at a minimum in
	4	Fig. 30). The conical end portions of each roller 902
.0	5	each run on a respective one of two conical races 906
	6	and 908 whose longitudinal separation determines the
	7	radial displacement of the rollers 902. The conical
15	8	races 906 and 908 are coupled for synchronous rotation
,,	9	but variable separation by means of a splined shaft 910
	10	which is rigid with the upper race 906 and non-
	11	rotatably slidable in the lower race 908. The tool 900
20	12	has a hollow core which hydraulically couples through
20	13	an upper sub 912 to a drillstring (not shown) which
	14	both selectively rotates the tool 900 within
	15	surrounding casing 990 which is to be profiled/expanded
25	16	by the tool 900 and transmits controllable hydraulic
20	17	pressure to the core of the tool 900 for controlling
	18	the roller displacement as will now be detailed.
30	19	The lower end of the tool 900 (with which the lower
30	20	race 908 is integral) is formed as hollow cylinder 914
	21	within which a piston 916 is slidably sealed. The
	22	piston 916 is mounted on the lower end of a downward
35	23	extension of the shaft 910 which is hollow to link
33	24	through the tool core and the drillstring to the
	25	controlled hydraulic pressure. The piston 916 divides
	26	the cylinder 914 into upper and lower parts. The upper
40	27	part of the cylinder 914 is linked to the controlled
40	28	hydraulic pressure by way of a side port 918 in the
	29	hollow shaft 910, just above the piston 916. The lower
	30	part of the cylinder 914 is vented to the outside of
45	31	the tool 900 through a hollow sub 920 which constitutes
45	32	the lower end of the tool 900 (and which enables
	33	further components, tools, or drillstring (not shown))
	34	to be connected below the tool 900). Thereby a

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	1 2	controllable hydraulic pressure differential can be selectively created across the piston 916, with
	3	consequent control of the longitudinal separation of
10	4	the two roller-supporting conical races 906 and 908
	5	which in turn controls the effective rolling diameter
	6	of the tool 900.
15	7	While certain modifications and variations of the
	8	invention have been described above, the invention is
	9	not restricted thereto, and other modifications and
	10	variations can be adopted without departing from the
20	11	scope of the invention as defined in the appended
	12	claims.
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<i>4</i> 5		
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## Claims

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	1	CLAIMS :
40	2	1. A method of profiling a pipe or other hollow tubular
10	3	article, the method comprising the steps of applying a
	4	roller means to a part of the pipe bore selected to be
	5	profiled, translating the roller means across the bore
	6	in a direction including a circumferential component
15	7	while applying a force to the roller means in a
	8	radially outwards direction with respect to the
	9	longitudinal axis of the pipe, and continuing such
	10	translation and force application until the pipe is
20	11	plastically deformed substantially into the intended
	12	profile.
	13	2. A method according to claim 1 wherein the
25	14	deformation of the pipe is accomplished by radial
	15	compression of the pipe wall, or by circumferential
	16	stretching of the pipe wall, or by a combination of
	17	such radial compression and circumferential stretching.
30		
	18	3. A method according to claim 1 or claim 2 wherein
	19	said direction is purely circumferential.
35	20	4. A method according to claim 1 or claim 2 wherein
	21	said direction is partly circumferential and partly
	22	longitudinal.
40	23	5. A method according to any preceding claim wherein
	24	said roller means is peripherally profiled to be
	25	complementary to the profile into which the selected
	26	part of the pipe bore is intended to be formed.
45		
	27	6. A method according to any preceding claim wherein
	28	the selected part of the pipe bore is remote from an
	29	open end of the pipe, and the method comprises the
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3	1	further steps of inserting the roller means into the
	2	open end of the pipe (if the roller means is not
	3	already in the pipe), and transferring the roller means
	4	along the pipe to the selected location.
10	5	drong the pipe to the streeted location.
	6	7. A method as claimed in claim 6 wherein transfer of
	7	the roller means is accomplished by the step of
	8	actuating traction means coupled to or forming part of
15	9	the roller means and effective to apply along-pipe
	10	traction forces to the roller means by reaction against
	11	<del>-</del>
	11	parts of the pipe bore adjacent the roller means.
20	12	8. A method of conjoining two pipes or other hollow
	13	tubular articles, said method comprising the steps of
	13	locating one of the two pipes within and longitudinally
	15	overlapping one of the other of the two pipes, applying
25	16	
		roller means to a part of the bore of the inner of the
	17	two pipes at a location where it is intended that the
	18	two pipes be conjoined, translating the roller means
30	19	across the bore in a direction including a
	20	circumferential component while applying a radially
	21	outwardly directed force to the roller means, and
	22	continuing such translation and force application until
35	23	the inner pipe is plastically deformed into permanent.
	24	contact with the outer pipe and is thereby conjoined
	25	thereto.
40	26	9. A method according to claim 8 wherein said
.•	27	deformation is accomplished by radial compression of
	28	the pipe wall, or by circumferential stretching of the
	29	pipe wall, or by a combination of such radial
45	30	compression and circumferential stretching.
45		
	31	10. A method according to claim 8 or claim 9 wherein
	32	said direction is purely circumferential.
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<b>J</b>	1	11. A method according to claim 8 or claim 9 wherein
	2	said direction is partly circumferential and partly
	3	longitudinal.
10		<b>3</b>
10	4	12. A method according to any of claims 8 to 11 whereir
	5	the location where the pipes are intended to be
	6	conjoined is remote from an accessible end of the bore,
40	7	and the method comprises the further steps of inserting
15	8	the roller means into the accessible end of the bore
	9.	(if the roller means is not already in the bore), and
	10	transferring the roller means to the intended location.
••		
20	11	13. A method according to claim 12 wherein transfer of
	12	the roller means is accomplished by the step of
	13	actuating traction means coupled to or forming part of
05	14	the roller means and effective to apply along-bore
25	15	traction forces to the roller means by reaction against
	16	parts of the pipe bore adjacent the roller means.
•		
20	17	14. Apparatus for expanding a pipe or other hollow
30	18	tubular article, said apparatus comprising roller means
	19	constructed or adapted for rolling deployment against
	20	the bore of the pipe, said roller means comprising at
25	21	least one set of individual rollers each mounted for
35	22	rotation about a respective rotation axis which is
	23	generally parallel to the longitudinal axis of the
	24	apparatus, the rotation axes of said at least one set
	25	of rollers being circumferentially distributed around
40	26	the expansion apparatus and each being radially offset
	27	from the longitudinal axis of the expansion apparatus,
	28	the expansion apparatus being selectively rotatable
	29	around its longitudinal axis.
45		
	30	15. Apparatus according to claim 14 wherein the
	31	rotation axes of said at least one set of rollers

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	1	conform to a first regime in which each said rotation
	2	axis is substantially parallel to the longitudinal axis
	3	of the apparatus in a generally cylindrical
10	4	configuration.
		•
	5	16. Apparatus according to claim 14 wherein the
	6	rotation axes of said at least one set of rollers
15	7	conform to a second regime in which each said rotation
	8	axis lies substantially in a respective radial plane
	9	including the longitudinal axis of the apparatus and
	10	the rotation axes each converge substantially towards a
20	11	common point substantially on the longitudinal axis of
	12	the apparatus in a generally conical configuration.
	13	17. Apparatus according to claim 14 wherein the
	14	rotation axes of said at least one set of rollers
25	15	conform to a third regime in which each said rotation
	16	axis is similarly skewed with respect to the
	17	longitudinal axis of the apparatus in a generally
	18	helical configuration which is either non-convergent
30	19	(cylindrical) or convergent (conical).
	20	18. Apparatus according to any of claims 14 to 17
	21	wherein the apparatus has only a single such set of
35	22	rollers.
	23	19. Apparatus according to any of claims 14 to 17
	24	wherein the apparatus has a plurality of such sets of
40	25	rollers.
	26	20. Apparatus according to claim 19 wherein the sets of
	27	rollers conform to two or more different ones of the
45	28	three regimes of roller axis alignments defined in
	29	claims 15-17.

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	1	21. Apparatus according to claim 20 wherein the
	2	apparatus has a set of rollers conforming to the second
	3	regime located at leading end of the apparatus and
10	4	another set of rollers conforming to the first regime
	5	located elsewhere on the apparatus.
	6	22. Apparatus according to claim 21 modified by the
15	7	addition of a further set of rollers conforming to
	8	third regime with non-convergent axes, this further set
	9	of rollers being utilised for the purpose of applying
	10	traction forces to the apparatus.
20		
	11	22. Apparatus according to any of claims 14 to 21
	12	wherein the rollers of said apparatus are each mounted
	13	for rotation about its respective rotation axis
25	14	substantially without freedom of movement along its
	15	respective rotation axis.
	16	23. Apparatus according to any of claims 14 to 21
20	17	wherein the rollers of said apparatus are each mounted
30	. 18	for rotation about its respective rotation axis with
	19	freedom of movement along its respective rotation axis,
25	20	24. Apparatus according to claim 23 wherein said
35	21	rollers have freedom of movement which is constrained
	22	within predetermined limits of movement.
	23	25. Apparatus for profiling or conjoining pipes or
40	24	other hollow tubular articles, said apparatus
	25	comprising roller means and radial urging means
	26	selectively operable to urge the roller means radially
	27	outwards of a longitudinal axis of the apparatus, the
45	28	radial urging means causing or allowing the roller
	29	means to move radially inwards towards the longitudinal
	30	axis of the apparatus when the radial urging means is

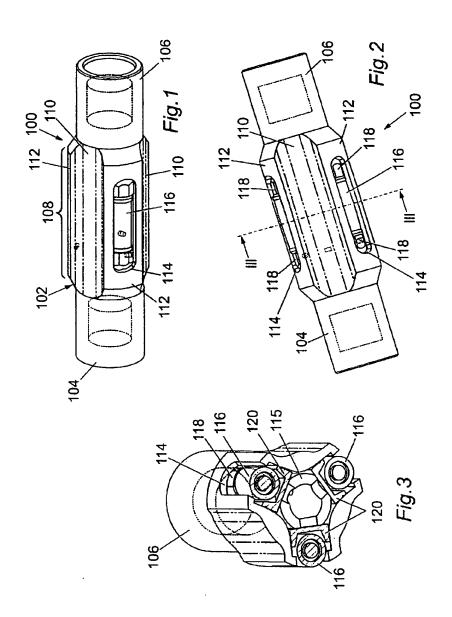
WO 00/37766 PCT/GB99/04225 5 not operated, the roller means comprising a plurality 1 of individual rollers each mounted for rotation about a respective rotation axis which is substantially parallel to the longitudinal axis of the apparatus, the 10 rotation axes of the individual rollers being circumferentially distributed around the apparatus and each said rotation axis being radially offset from the longitudinal axis of the apparatus, the apparatus being 15 9 selectively rotatable around its longitudinal axis to 10 translate the roller means across the bore of a pipe against which the roller means is being radially urged. 11 12 20 13 26. Apparatus according to claim 25 wherein the radial 14 urging means comprises a respective piston on which each said roller is individually rotatably mounted, 15 16 each said piston being slidably sealed in a respective 25 17 radially extending bore formed in a body of the 18 apparatus, a radially inner end of each said bore being 19 in fluid communication with fluid pressure supply means selectively pressurisable to operate said radial urging 20 30 21 means. 22 27. Apparatus according to claim 25 wherein the radial 23 urging means comprises bi-conical race means upon which 35 24 each said individual roller rolls in use of the 25 apparatus, and separation variation means selectively operable controllably to vary the longitudinal 26 27 separation of the two conical races of the bi-conical 40 28 race means whereby correspondingly to vary the radial displacement of each said roller rotation axis from the 29 longitudinal axis of the apparatus. 30 45 31 28. Apparatus according to claim 27 wherein the 32 separation variation means comprises hydraulic linear

motor means selectively pressurisable to drive one of

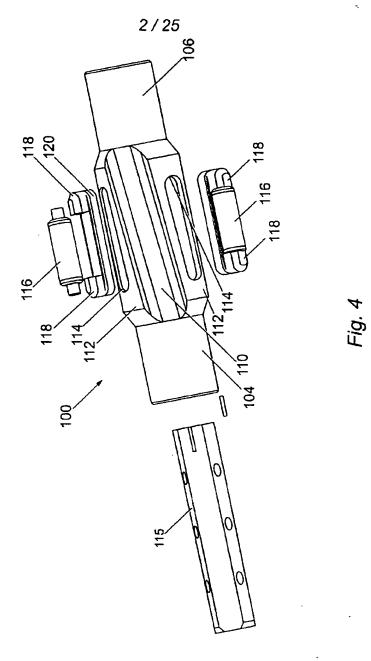
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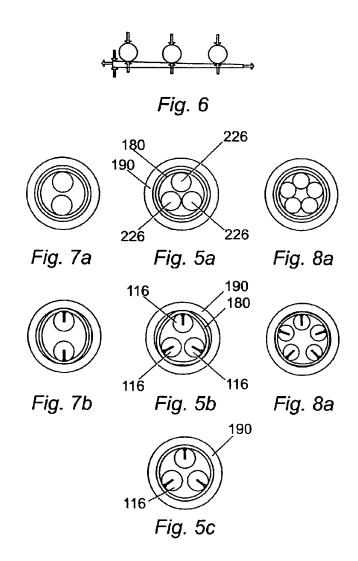
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	1	said two cones longitudinally towards and/or away from
	2	the other said cone.
10	3	29. A method of expanding an inner pipe into an outer
	4	pipe, said method comprising effecting rolling
	5	compressive yield of the wall of the inner pipe wall to
	6	cause reduction in wall thickness and subsequent
15	7	increase in circumference resulting in diameter
	8	increase.
	9	30. A method as claimed in Claim 29, wherein the method
20	10	generates compressive hoop stress in the inner pipe
	11	resulting in an interference fit of the inner pipe
	12	within the outer pipe.
25	13	31. A method as claimed in Claim 30, wherein the
23	14	resulting interference fit can withstand a high level
	15	of longitudinal force resulting from tensile or
	16	compressive stress.
30	17	32. A method of creating a high pressure seal between
	18	an inner pipe and an outer pipe by creating a metal to
	19	metal interface between the pipes by effecting rolling
	20	compressive yield of the inner pipe within the outer
35	21	pipe.
	22	33. A method as claimed in Claim 32, including the
	23	addition of elastomer or ductile metal seals between
40	24	the inner pipe and outer pipe.

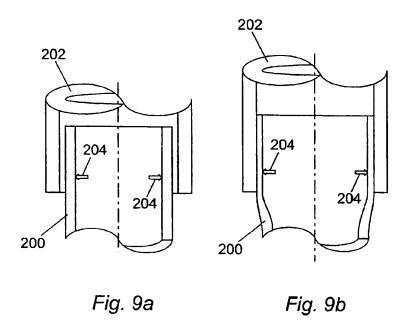


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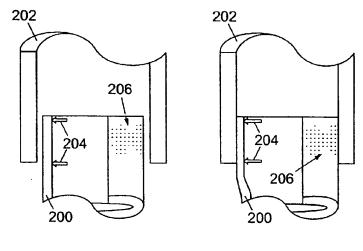
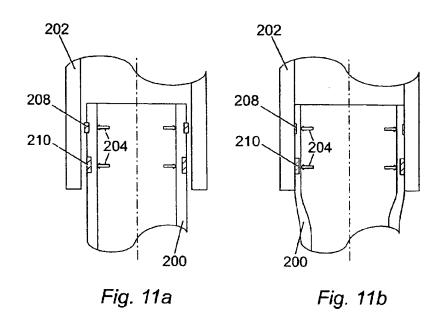
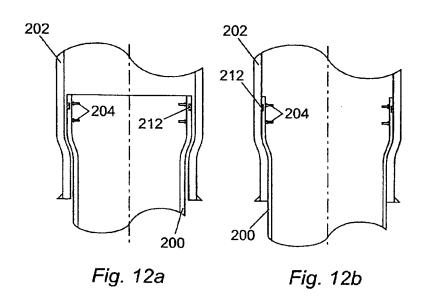


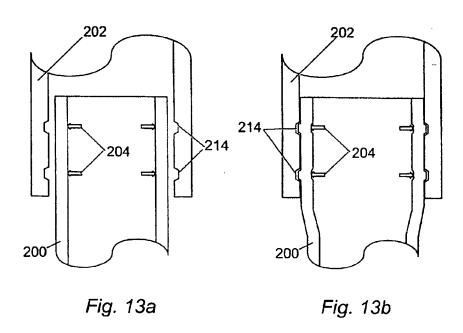
Fig. 10a

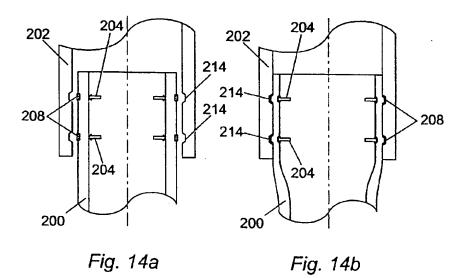
Fig. 10b





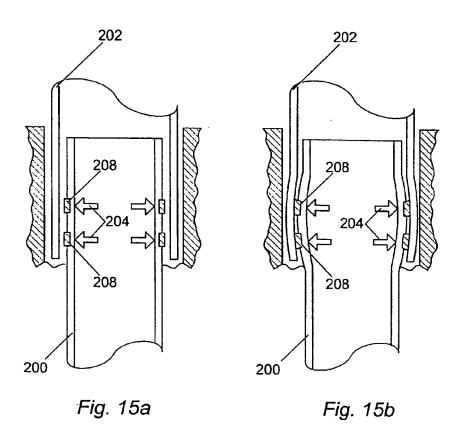
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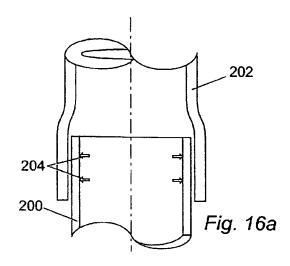


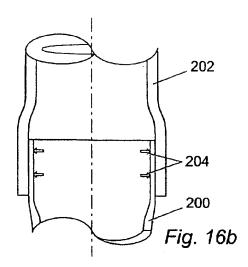
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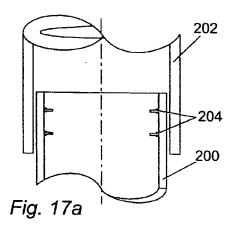


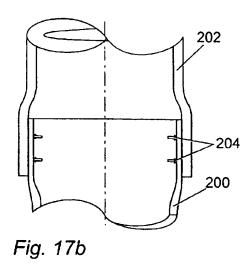
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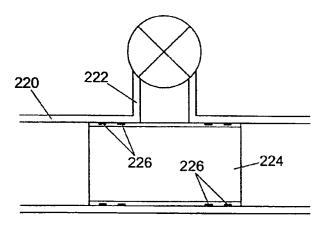


Fig. 18

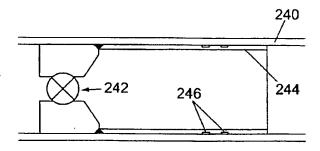
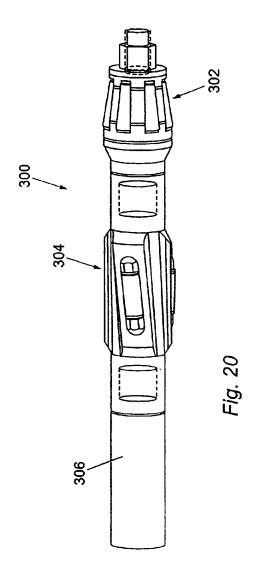
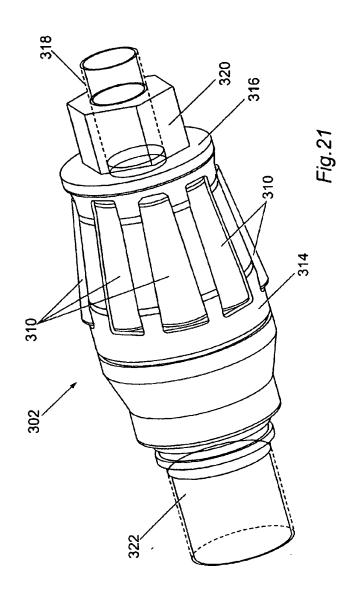


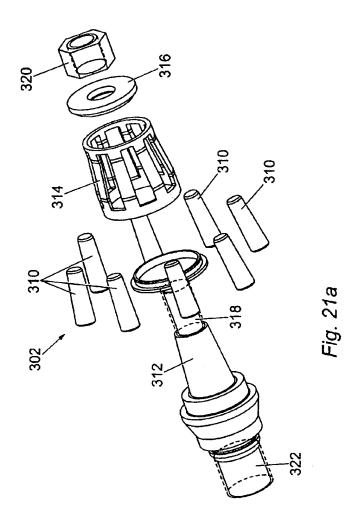
Fig. 19



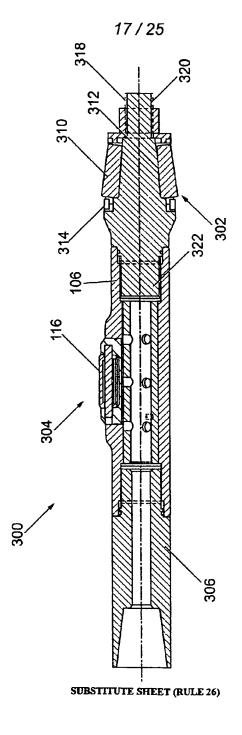
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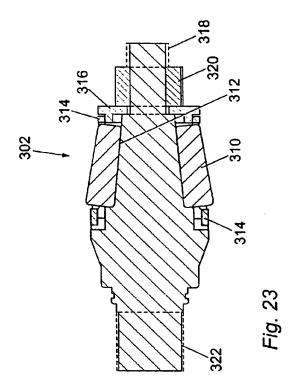
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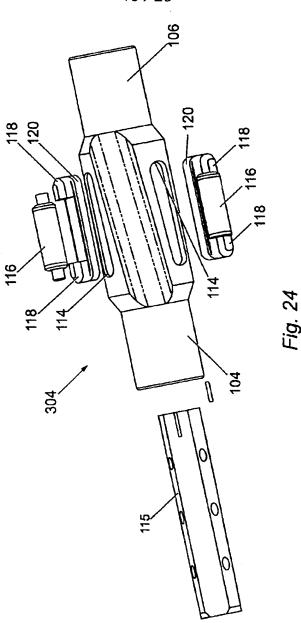


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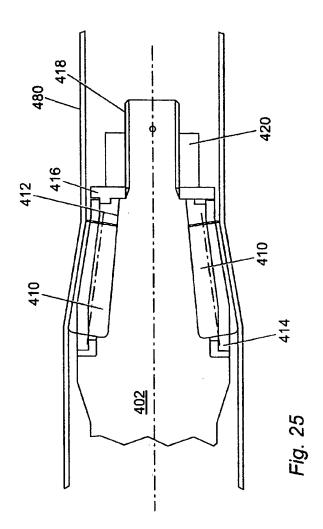


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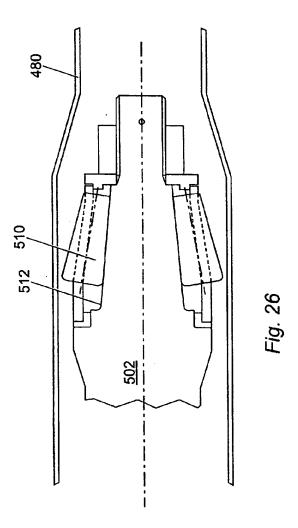




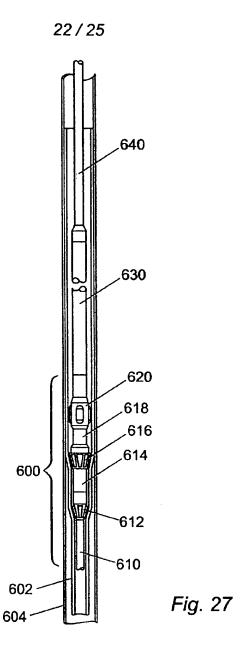
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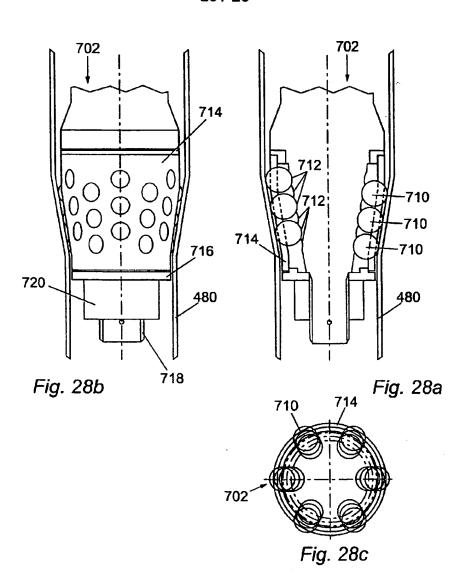


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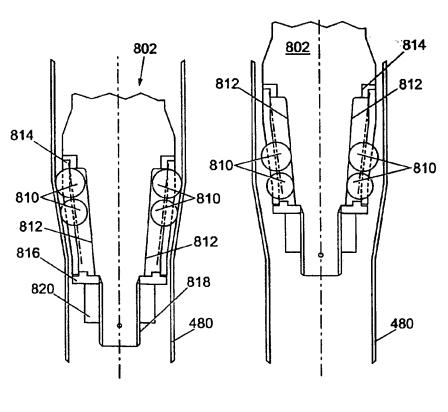


Fig. 29a

Fig. 29b

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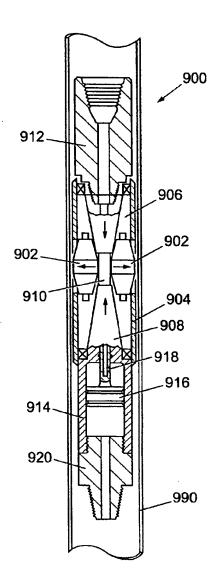


Fig. 30

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# INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(60) Parent Application or Grant

WEATHERFORD/LAMB, INC. [/]; (). SIMPSON, Neil, Andrew, Abercrombie [/]; (). SIMPSON, Neil, Andrew, Abercrombie [/]; (). HARDING, Richard, Patrick; ().

(54) Title: PROCEDURES AND EQUIPMENT FOR PROFILING AND JOINTING OF PIPES

(54) Titre: PROCEDES ET MATERIEL DE FAÇONNAGE ET D'ASSEMBLAGE DE TUYAUX

#### (57) Abstract

Methods and apparatus for shaping pipes, tubes, liners, or casing at downhole locations in wells. Use is made of rollers bearing radially outwards against the inside wall of the pipe (etc.), the rollers being rolled around the pipe to cause outward plastic deformation which expands and shapes the pipe to a desired profile. Where one pipe is inside another, the two pipes can be joined without separate components (except optional seals). Landing nipples and liner hangers can be formed in situ. Valves can be deployed to a selected downhole location and there sealed to the casing or liner without separate packers. Casing can be deployed downhole in reduced-diameter lengths and then expanded to case a well without requiring larger diameter bores and casing further uphole. The invention enables simplified downhole working, and enables a well to be drilled and produced with the minimum downhole bore throughout its depth, obviating the need for large bores. When expanding lengths of casing, the casing does not need to be anchored or made pressure-tight. The profiling/expansion tools of the invention can be deployed downhole on coiled tubing, and operated without high tensile loads on the coiled tubing.

#### (57) Abrégé

L'invention concerne des procédés et appareils de façonnage de tuyaux, tubes, colonnes perdues ou tubages au fond de puits. On utilise des rouleaux disposés radialement vers l'extérieur contre la paroi intérieure du tuyau et on fait rouler les rouleaux autour du tuyau pour provoquer une déformation plastique vers l'extérieur qui gonfie le tuyau et le façonne dans une forme voulue. Lorsqu'un tuyau se trouve à l'intérieur d'un autre tuyau, on peut assembler les deux tuyaux sans recourir à des composants séparés (sauf éventuellement des joints). Des raccords à portée intérieure et des suspensions de colonne perdue peuvent être formés sur place. On peut déployer des vannes dans un emplacement de fond sélectionné puis les assembler au tubage ou à la colonne perdue sans garniture d'étanchéité séparée. On peut déployer le tubage au fond par longueurs de diamètre réduit, puis le dilater pour le transformer en gainage d'un puits sans devoir creuser de trous à diamètre plus large et sans utiliser d'avantage de tubage vers la tête du puits invention simplifie le travail de forage et permet de creuser un trou de forage avec un alésage minimal en profondeur, ce qui élimine la nécessité de creuser des trous à large diamètre. Lors de la dilatation d'un tubage, le tubage ne doit pas nécessairement être ancré ou étanche. Les outils de faconnage/expansion de l'invention peuvent être déployés au fond sur un serpentin et actionnés sans provoquer d'efforts de tension élevés sur le serpentin



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# INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(71) Applicant (for all designated States except US): ASTEC DE-VELOPMENTS LIMITED [GB/GB]; Burn of Daff Farm, Downies, Portlethen, Aberdeen AB1 4QX (GB).

(72) Inventor; and

(75) Investor/Applicant (for US only): SIMPSON, Neil, Andrew, Abercrombie [GB/GB]; Burn of Daff Farm, Downies, Portlethen, Aberdeen AB1 4QX (GB).

(74) Agent: PACITTI, Paolo; Murgitroyd & Company, 373 Scotland Street, Glasgow G5 8QA (GB).

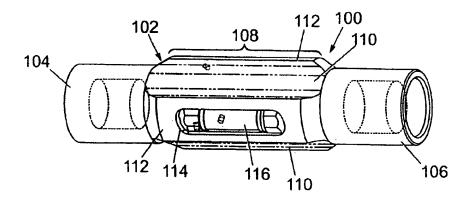
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#### (57) Abstract

Methods and apparatus for shaping pipes, tubes, liners, or easing at downhole locations in wells. Use is made of rollers bearing radially outwards against the inside wall of the pipe (etc.), the rollers being rolled around the pipe to cause outward plastic deformation which expands and shapes the pipe to a desired profile. Where one pipe is inside another, the two pipes can be joined without separate components (except optional seals). Landing nipples and liner hangers can be formed in situ. Valves can be deployed to a selected downhole location and there sealed to the casing or liner without separate packers. Casing can be deployed downhole in reduced—diameter lengths and then expanded to case a well without requiring larger diameter bores and casing further uphole. The invention enables simplified downhole working, and enables a well to be drilled and produced with the minimum downhole bore throughout its depth, obviating the need for large bores. When expanding lengths of casing, the casing does not need to be anchored or made pressure—tight. The profiling/expansion tools of the invention can be deployed downhole on colled tubing, and operated without high tensile loads on the coiled tubing.

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	US 2 754 577 A (C.A. MAXWELL)	8,9,11.
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	column 2, line 21-39 column 3, line 39-42	
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X	US 2 898 971 A (G.A. HEMPEL)	8-10,
,,,	11 August 1959 (1959-08-11)	29-31
	claim 1; figures 1-5	
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	column 2, line 43-51; figure 2	
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## FURTHER INFORMATION CONTINUED FROM PCT/ISAV 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-7,14-28

Method and apparatus for profiling a pipe or other hollow tubular article,

2. Claims: 8-13,29-33

A method of conjoining two pipes or other hollow tubular articles.  $% \left( 1\right) =\left( 1\right) \left( 1\right)$ 

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